AMENDMENTS TO THE SPECIFICATION

Please replace the paragraph beginning at line 8 on page 1 of the specification with the following rewritten paragraph.

Conventional equipment using ~~a~~ linear vibration motors include vibration generators that ~~informs~~ inform of incoming calls by mechanical vibration, such as handy phones, compressors that compress and circulate gas or liquid, and reciprocating electric razors. In this specification, the handy phones refer to portable phones such as mobile phones and cellular phones. The compressors and the reciprocating electric razors use the linear vibration motors as their driving sources.

Please replace the paragraph beginning at line 15 on page 3 of the specification with the following rewritten paragraph.

So, as a method for detecting the position of the piston ~~72~~, there is proposed a method of directly measuring the linear motor driving current and voltage which are supplied to the linear vibration motor, and deriving the position of the mover on the basis of the measured values, without using a position sensor placed in the linear vibration motor (refer to Japanese Unexamined Patent Publication No.Hei.8-508558).

Please replace the paragraph beginning at line 22 on page 4 of the specification with the following rewritten paragraph.

The equivalent circuit shown in figure 11 is derived from ~~the~~ Kirchhoff's ~~low~~law, and an instantaneous velocity v [m/s] of the linear vibration motor is obtained from the equivalent circuit.

Please replace the paragraph beginning at line 11 on page 6 of the specification with the following rewritten paragraph.

To be more specific, when the compressor to which the linear vibration motor is applied is under a loaded condition, the mover center position (mover amplitude center position) in the mover reciprocating motion is offset with respect to the mover neutral

position (i.e., the mover amplitude center position when the pressure in the compression chamber is equal to the back pressure) due to the pressure of a cooling medium gas, and the mover reciprocates around the offset mover amplitude center position. In other words, the mover displacement x obtained by formula (2) includes an average component.

Please replace the paragraph beginning at line 1 on page 10 of the specification with the following rewritten paragraph.

Under the state where the linear compressor draws in a cooling medium gas (suction state), i.e., under the state where the inlet valve is open, both of the pressure in the compression chamber and the pressure on the back of the mover are equal to the cooling medium inlet pressure. This is because the linear compressor is constructed so that the differential pressure becomes zero under the state where the inlet valve is open. In this state, a force from the pressure of the cooling medium that acts on the mover can be ignored. That is, in this state, the forces acting on the mover are only the repulsive force of the spring that is generated by bending of the support spring and the electromagnetic force that is generated by applying a current to the linear vibration motor. According to ~~the~~ Newton's ~~low~~ law of motion, the sum of these forces is equal to the product of the total mass of the movable member that is moving, and its acceleration.

Please replace the paragraph beginning at line 5 on page 16 of the specification with the following rewritten paragraph.

In addition, according to the present invention, the processing for calculating the spring constant is performed after assembling the linear vibration motor. Accordingly, the following effect is also achieved ~~with~~ relative to the case where the calculation of the spring constant is performed at the assembly of the linear vibration motor.

Please replace the paragraph beginning at line 12 on page 20 of the specification with the following rewritten paragraph.

According to a 6th aspect of the present invention, in the motor driving apparatus of any of the 1st to 4th aspects, the timing detection unit detects the timing when the freely vibrating mover passes through the prescribed relative position with respect to the reference position of the vibration using an induced voltage that occurs on a coil of the linear vibration motor due to the free vibration of the mover. Therefore, it is possible to ~~calculates~~ calculate the natural frequency period or the like of the mover that is freely vibrating using a component such as the existing voltage detector, without using a special position sensor, whereby the number of components can be reduced, resulting in reduction of the size or cost of the apparatus.

Please replace the paragraph beginning at line 20 on page 26 of the specification with the following rewritten paragraph.

In addition, according to the present invention, the processing for calculating the mass/spring ratio is performed after assembling the linear vibration motor. Accordingly, the following effect is also achieved ~~with~~ relative to the case where the calculation of the mass/spring ratio is performed at the assembly of the linear vibration motor.

Please replace the paragraph beginning at line 10 on page 45 of the specification with the following rewritten paragraph.

The motor driving apparatus 101a further includes a mover force vibration unit 3a for temporarily applying a force (forced vibration force) Ffv so that the mover of the linear vibration motor 100 freely vibrates, a relative position detection unit 4a for detecting a timing when the mover passes through a prescribed relative position Pr with respect to a vibration reference position such as the center of the vibration under the freely vibrating state of the mover and outputting timing information Dpr which indicates the detected timing, a natural frequency detection unit 5a for detecting a natural frequency f of the mover on the basis of the timing information Dpr outputted from the relative position detection unit 4a, and a spring constant decision unit 6a for deciding

(calculating) a spring constant k of the spring member from the detected natural frequency f and outputting spring constant information Dk that indicates the decided (calculated) spring constant to the mover position detection unit 2a. Strictly speaking, the above-mentioned natural frequency f is a natural frequency of a spring vibration system including the mover.

Please replace the paragraph beginning at line 18 on page 46 of the specification with the following rewritten paragraph.

The linear vibration motor 100 includes a stator, a mover, and a spring member that supports the mover so as to form a spring vibration system including the mover. The driving frequency of the linear vibration motor 100 is a resonance frequency of the reciprocating motion of the mover, i.e., the resonance frequency of the spring vibration system, or a frequency that is close to the resonance frequency. Further, the stator comprises ~~by~~ an electromagnet that is obtained by winding a coil around an iron core, and the mover comprises a permanent magnet.

Please replace the paragraph beginning at line 2 on page 51 of the specification with the following rewritten paragraph.

The natural frequency detection unit 5a detects the natural frequency f of the mover from the timing information Dpr that is outputted from the relative position detection unit 4a. More specifically, the natural frequency detection unit 5a detects the number of times ~~of passing of~~ the freely vibrating mover passes through a fixed point (i.e., the relative position) per unit time, on the basis of the timing information Dpr from the relative position detection unit 4a. Usually, the center of the vibration of the mover is utilized as the relative position Pr.

Please replace the paragraph beginning at line 11 on page 51 of the specification with the following rewritten paragraph.

That is, the natural frequency detection unit 5a detects the natural frequency f of the mover by detecting the number of times ~~of passing of~~ the mover passes through the fixed point (the relative position) within a prescribed time. By extending this prescribed time, the accuracy of the detection of the natural frequency can be increased.

Please replace the paragraph beginning at line 10 on page 53 of the specification with the following rewritten paragraph.

The natural frequency detection unit 5a detects the natural frequency f of the mover on the basis of the timing information Dpr from the relative position detection unit 4a. More specifically, the natural frequency detection unit 5a detects the number of times ~~of passing of~~ the freely vibrating mover passes through the relative position within a prescribed time on the basis of the timing information Dpr, thereby obtaining the natural frequency f of the mover, and outputs frequency information Df that indicates the natural frequency f.

Please replace the paragraph beginning at line 19 on page 53 of the specification with the following rewritten paragraph.

The spring constant decision unit 6a calculates the spring constant k on the basis of the frequency information Df from the natural frequency detection unit 5a ~~k~~ by multiplying the natural frequency f indicated by the frequency information Df by a twofold of the ratio of the circumference to the diameter (π), and squaring the result of the multiplication, and further multiplying the squared value by the mass of the mover, and outputs spring constant information Dk that indicates the spring constant to the mover position calculation unit 2a.

Please replace the paragraph beginning at line 13 on page 57 of the specification with the following rewritten paragraph.

On the other hand, in the case of calculating the spring constant after the assembly of the linear vibration motor as in this first embodiment, the complicated processing for correcting the default of the spring constant of the motor driving apparatus are not required at the assembly. Further, the value of the spring constant that is held in the motor driving apparatus is set in the state where the driving apparatus is combined with the linear vibration motor. Therefore, even when either the linear vibration motor or the driving apparatus is broken, it is possible to set the spring constant of the motor driving apparatus after the broken member is changed. In other words, when one of the motor and the driving apparatus is broken, ~~all that required is~~<u>the</u> only <u>requirement is</u> changing ~~of~~ the broken member.

Please replace the paragraph beginning at line 8 on page 69 of the specification with the following rewritten paragraph.

As the method for obtaining the natural frequency period, there is not only the above-mentioned method of directly detecting a time period that is required for the mover to go back and forth one time, but also a method of detecting the number of times ~~of passing of~~ the mover <u>passes</u> through a fixed point within a prescribed time period, thereby detecting the natural frequency, and calculating the natural frequency period from the detected natural frequency. In this case, by making the prescribed time period, i.e., the time period for measuring the number of times ~~of passing of~~ the mover <u>passes</u> through the fixed point, longer, the accuracy in the detection of the natural frequency period can be increased.

Please replace the paragraph beginning at line 19 on page 73 of the specification with the following rewritten paragraph.

More specifically, the motor driving apparatus 101d according to the fourth embodiment includes a motor driver 1d for driving/controlling the linear vibration motor

100 on the basis of position information Dpc that indicates the position Px of the mover, and a mover position calculation unit 2a for performing ~~for performing~~ position calculation of calculating the position Px of the mover on the basis of the spring constant k of the spring member in the linear vibration motor 100.

Please replace the paragraph beginning at line 1 on page 84 of the specification with the following rewritten paragraph.

In addition, in this fourth embodiment, the motor driving apparatus 101d has the two operation modes, i.e., the driving mode and the arithmetic mode~~, and in~~. In the driving mode, ~~it~~ the motor driving apparatus 101d drives the linear vibration motor 100 at a driving voltage value (or a driving current value) corresponding to a required motor output, while in the arithmetic mode, ~~detecting~~ the motor driving apparatus 101d detects the resonance frequency of the linear vibration motor 100 and ~~obtaining~~ obtains (calculates) the spring constant on the basis of the detected resonance frequency. However, it is also possible that the motor driving apparatus 101d has only one operation mode (driving mode) for operating the load of the linear vibration motor and, in this driving mode, detects the resonance frequency of the linear vibration motor and drives the linear vibration motor at the detected resonance frequency as well as decides (calculates) the spring constant k on the basis of the detected resonance frequency.

Please replace the paragraph beginning at line 9 on page 87 of the specification with the following rewritten paragraph.

Here, the temperature detection unit 12e comprises a temperature sensor that is mounted on the linear vibration motor 100 to monitor the motor temperature Tm. The spring constant decision unit 6a is identical to that in the first embodiment. More specifically, the spring constant decision unit 6a decides (calculates) the spring constant k by multiplying the natural frequency fpv that is detected by the natural frequency detection unit 5a by a twofold of the ratio of the circumference to the diameter, squaring the result of the multiplication, and further multiplying the squared value by the mass of

the mover, and outputs spring constant information Dk that indicates the decided spring constant k. In the arithmetic mode, the spring constant estimation unit 13e derives a spring constant-temperature function Qa that shows a relationship between the spring constant k and the motor temperature Tm on the basis of the spring constant information Dk and the temperature information Dtm ~~and, in~~. In the driving mode, the spring constant estimation unit 13e estimates the spring constant of the linear vibration motor that is operated in the loaded state from the detected motor temperature Tm using the spring constant-temperature function Qa, and outputs estimated spring constant information Dk(t) that indicates the estimated spring constant k(t). Here, the spring constant estimation unit 13e performs the derivation of the spring constant-temperature function Qa on the basis of a temperature coefficient αk of the spring member, which indicates a ratio of a change in the spring constant ~~with~~ relative to the change in the temperature. More specifically, the spring constant estimation unit 13e holds a temperature coefficient αk depending on the spring member in its internal memory, and derives the spring constant-temperature function Qa as a linear function that indicates the correspondence between the spring constant k and the motor temperature Tm from the spring constant k of the spring member, which has been decided in the arithmetic mode by the spring constant decision unit 6a, the motor temperature Tm which has been detected in the arithmetic mode by the temperature detection unit 12e, and the temperature coefficient αk of the spring member, which is held in the internal memory.

Please replace the paragraph beginning at line 7 on page 90 of the specification with the following rewritten paragraph.

The natural frequency detection unit 5a detects the natural frequency f of the spring vibration system on the basis of the timing information Dpr from the relative position detection unit 4a. More specifically, the natural frequency detection unit 5a detects the number of times ~~of passing of~~ the freely vibrating mover passes through a fixed point (usually, the center of the vibration of the mover) within a prescribed time period, and outputs frequency information Df that indicates the natural frequency f.

Please replace the paragraph beginning at line 4 on page 118 of the specification with the following rewritten paragraph.

Further, in this ninth embodiment, the motor driving apparatus 101i has the two operation modes, i.e., the driving mode and the arithmetic mode~~, and in~~. In the driving mode, the motor driving apparatus 101i drives the linear vibration motor 100 at a driving frequency corresponding to a required motor output, while in the arithmetic mode, ~~driving~~ the motor driving apparatus 101i drives the linear vibration motor 100 at the resonance frequency in accordance with the driving frequency control signal Sfc from the resonance frequency detection unit 11d. However, it is also possible that the motor driving apparatus 101i has only one operation mode (driving mode) for operating the load of the linear vibration motor and, in this driving mode, ~~it~~ the motor driving apparatus 101i detects the resonance frequency of the linear vibration motor, ~~and~~ drives the linear vibration motor at the detected resonance frequency, and ~~as well as~~ decides the mass/spring ratio rmk on the basis of the detected resonance frequency, as described in the fourth embodiment.

Please replace the paragraph beginning at line 1 on page 130 of the specification with the following rewritten paragraph.

The linear compressor 40 has a cylinder section 41a and a motor section 41b which are adjacent to each other along a predetermined axis line. In the cylinder section 41a, a piston 42 which is slidably supported along the axis direction is placed. A piston rod 42a ~~an~~ whose one end ~~of which~~ is fixed to the rear side of the piston 42 is placed across the cylinder section 41a and the motor section 41b, and a support spring 43 which applies a force to the piston rod 42a in the axis direction is provided on the other end of the piston rod 42a. Here, the support spring 43 corresponds to the spring member of the linear vibration motor 100 according to the first embodiment.

Please replace the paragraph beginning at line 1 on page 133 of the specification with the following rewritten paragraph.

More specifically, the air conditioner 212 according to the twelfth embodiment has the linear compressor 50a, a four-way valve 54, a throttle (expansion valve) 53, an indoor heat exchanger 51, an outdoor heat exchanger 52, which ~~forms~~ form a refrigerant circulation path, and the motor driving unit 50b for driving the linear vibration motor as a driving source of the linear compressor 50a.

Please replace the paragraph beginning at line 18 on page 134 of the specification with the following rewritten paragraph.

The indoor heat exchanger 51 operates as a condenser during heating and as an evaporator during cooling. The outdoor heat exchanger 52 operates as an evaporator during heating and as a condenser during cooling. In the condenser, the high-temperature and high-pressure refrigerant gas flowing therein loses heat to the air blown into the condenser, and gradually liquefies, resulting in a high-pressure liquid refrigerant in the vicinity of the outlet of the condenser. This is equivalent to ~~that~~ the refrigerant ~~radiates~~ radiating heat into the air to liquefy. Further, the liquid refrigerant whose temperature and pressure are reduced by the throttle 53 flows into the evaporator. When the indoor air is blown into the evaporator in this state, the liquid refrigerant takes a great amount of heat from the air and evaporates, resulting in a low-temperature and low-pressure gas refrigerant. The air which has lost a great amount of heat in the evaporator is discharged as cool air from the blowoff port of the air conditioner.

Please replace the paragraph beginning at line 20 on page 136 of the specification with the following rewritten paragraph.

As described above, in the air conditioner 212 according to the twelfth embodiment, since the compressor (linear compressor) 50a having the linear vibration motor as a power source is used as the compressor for compressing and circulating a refrigerant, friction loss in the compressor is reduced as compared with an air conditioner using a compressor having a rotation-type motor as a power source, and furthermore,

sealability of the compressor for sealing a high-pressure refrigerant and a low-pressure refrigerant is enhanced, resulting in an increase in efficiency of the compressor.

Please replace the paragraph beginning at line 14 on page 140 of the specification with the following rewritten paragraph.

As described above, in the refrigerator 213 according to the thirteenth embodiment, since the linear compressor 60a having the linear vibration motor as a power source is used as the compressor for compressing and circulating the refrigerant, friction loss in the compressor is reduced as compared with a refrigerator using a compressor having a rotation-type motor as a power source, and furthermore, sealability for sealing the refrigerant in the compressor is enhanced, resulting in an increase in operation efficiency of the compressor, like in the air conditioner 212 of the twelfth embodiment.

Please replace the paragraph beginning at line 6 on page 141 of the specification with the following rewritten paragraph.

Moreover, in the ~~air conditioner~~refrigerator 213, the motor driving apparatus 60b calculates the spring constant k of the spring member in the arithmetic mode in which the linear vibration motor is not operated and then calculates the position of the mover of the linear vibration motor using the calculated spring constant k in the driving mode in which the linear vibration motor is operated, ~~like~~ as in the motor driving apparatus 211 according to the eleventh embodiment. Therefore, it is possible to detect the position of the piston with high accuracy during the operation of the linear compressor 60a. Accordingly, the clearance between the piston and the cylinder head can be reduced, resulting in miniaturization of the linear compressor, which leads to miniaturization of the refrigerator.

Please replace the paragraph beginning at line 25 on page 151 of the specification with the following rewritten paragraph.

As described above, in the hot-water supply unit 215 according to the fifteenth embodiment, since the linear compressor 80a having the linear vibration motor as a power source is used as the compressor for compressing and circulating the refrigerant in the refrigeration cycle unit 81a, friction loss in the compressor is reduced as compared with a hot-water supply unit using a compressor having a rotation-type motor as a power source, and furthermore, sealability for sealing the refrigerant in the compressor is enhanced, resulting in an increase in operation efficiency of the compressor, ~~like~~ as in the air conditioner 212 of the twelfth embodiment.

AMENDMENTS TO THE ABSTRACT

Please replace the abstract with the following substitute abstract. A clean version of the substitute abstract is attached hereto.

ABSTRACT ~~OF THE DISCLOSURE~~

~~An~~ A motor driving apparatus for driving a linear vibration motor having a spring member that supports a mover so as to form a spring vibration system including the mover.~~, which~~ The motor driving apparatus employs an accurate spring constant of the spring member corresponding to an individual linear vibration motor at a position calculation for obtaining the position of the mover during the operation, thereby increasing the accuracy of the position calculation. ~~This~~ The motor driving apparatus includes a mover force vibration unit for making the mover of the linear vibration motor freely vibrate, a relative position detection unit for detecting a timing when the freely vibrating mover passes through a fixed point (relative position), and a natural frequency detection unit for detecting a natural frequency of the mover based on ~~the basis of~~ output information from the relative position detection unit, thereby ~~deciding~~ calculating the spring constant based on ~~the basis of~~ the detected natural frequency.